EPA/310-R-97-008

EPA Office of Compliance Sector Notebook Project:

PROFILE OF THE SHIPBUILDING AND REPAIR INDUSTRY

November 1997

Office of Compliance
Office of Enforcement and Compliance Assurance
U.S. Environmental Protection Agency
401 M St., SW (MC 2221-A)
Washington, DC 20460

This report is one in a series of volumes published by the U.S. Environmental Protection Agency (EPA) to provide information of general interest regarding environmental issues associated with specific industrial sectors. The documents were developed under contract by Abt Associates (Cambridge, MA), Science Applications International Corporation (McLean, VA), and Booz-Allen & Hamilton, Inc. (McLean, VA). This publication may be purchased from the Superintendent of Documents, U.S. Government Printing Office. A listing of available Sector Notebooks and document numbers is included at the end of this document.

All telephone orders should be directed to:

Superintendent of Documents
U.S. Government Printing Office
Washington, DC 20402
(202) 512-1800
FAX (202) 512-2250
8:00 a.m. to 4:30 p.m., EST, M-F

Using the form provided at the end of this document, all mail orders should be directed to:

U.S. Government Printing Office
P.O. Box 371954
Pittsburgh, PA 15250-7954

Complimentary volumes are available to certain groups or subscribers, such as public and academic libraries, Federal, State, and local governments, and the media from EPA's National Center for Environmental Publications and Information at (800) 490-9198. For further information, and for answers to questions pertaining to these documents, please refer to the contact names and numbers provided within this volume.

Electronic versions of all Sector Notebooks are available via Internet on the Enviroene World Wide Web. Downloading procedures are described in Appendix A of this document.

Cover photograph courtesy of Ingalls Shipbuilding Inc., Pascagoula, MS.

Sector Notebook Contacts

The Sector Notebooks were developed by the EPA's Office of Compliance. Questions relating to the Sector Notebook Project can be directed to:

Seth Heminway, Coordinator, Sector Notebook Project
US EPA Office of Compliance
401 M St., SW (2223-A)
Washington, DC 20460
(202) 564-7017

Questions and comments regarding the individual documents can be directed to the appropriate specialists listed below.

Document Number	Industry	Contact	Phone (202)
EPA/310-R-95-001.	Dry Cleaning Industry	Joyce Chandler	564-7073
EPA/310-R-95-002.	Electronics and Computer Industry	Steve Hoover	564-7007
EPA/310-R-95-003.	Wood Furniture and Fixtures Industry	Bob Marshall	564-7021
EPA/310-R-95-004.	Inorganic Chemical Industry	Walter DeRieux	564-7067
EPA/310-R-95-005.	Iron and Steel Industry	Maria Malave	564-7027
EPA/310-R-95-006.	Lumber and Wood Products Industry	Seth Heminway	564-7017
EPA/310-R-95-007.	Fabricated Metal Products Industry	Scott Throwe	564-7013
EPA/310-R-95-008.	Metal Mining Industry	Jane Engert	564-5021
EPA/310-R-95-009.	Motor Vehicle Assembly Industry	Anthony Raia	564-6045
EPA/310-R-95-010.	Nonferrous Metals Industry	Jane Engert	564-5021
EPA/310-R-95-011.	Non-Fuel, Non-Metal Mining Industry	Robert Lischinsky	564-2628
EPA/310-R-95-012.	Organic Chemical Industry	Walter DeRieux	564-7067
EPA/310-R-95-013.	Petroleum Refining Industry	Tom Ripp	564-7003
EPA/310-R-95-014.	Printing Industry	Ginger Gotliffe	564-7072
EPA/310-R-95-015.	Pulp and Paper Industry	Maria Eisemann	564-7016
EPA/310-R-95-016.	Rubber and Plastic Industry	Maria Malave	564-7027
EPA/310-R-95-017.	Stone, Clay, Glass, and Concrete Industry	Scott Throwe	564-7013
EPA/310-R-95-018.	Transportation Equipment Cleaning Ind.	Virginia Lathrop	564-7057
EPA/310-R-97-001.	Air Transportation Industry	Virginia Lathrop	564-7057
EPA/310-R-97-002.	Ground Transportation Industry	Virginia Lathrop	564-7057
EPA/310-R-97-003.	Water Transportation Industry	Virginia Lathrop	564-7057
EPA/310-R-97-004.	Metal Casting Industry	Jane Engert	564-5021
EPA/310-R-97-005.	Pharmaceuticals Industry	Emily Chow	564-7071
EPA/310-R-97-006.	Plastic Resin and Manmade Fiber Ind.	Sally Sasnett	564-7074
EPA/310-R-97-007.	Fossil Fuel Electric Power Generation Ind.	Rafael Sanchez	564-7028
EPA/310-R-97-008.	Shipbuilding and Repair Industry	Anthony Raia	564-6045
EPA/310-R-97-009.	Textile Industry	Belinda Breidenbach	564-7022
EPA/310-R-97-010.	Sector Notebook Data Refresh, 1997	Seth Heminway	564-7017

Page iv intentionally left blank.

SHIPBUILDING AND REPAIR INDUSTRY
(SIC 3731)
TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AFS - AIRS Facility Subsystem (CAA database)
AIRS - Aerometric Information Retrieval System (CAA database)
BIFs - Boilers and Industrial Furnaces (RCRA)
BOD - Biochemical Oxygen Demand
CAA - Clean Air Act
CAAA - Clean Air Act Amendments of 1990
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS - CERCLA Information System
CFCs - Chlorofluorocarbons
CO - Carbon Monoxide
COD - Chemical Oxygen Demand
CSI - Common Sense Initiative
CWA - Clean Water Act
D&B - Dun and Bradstreet Marketing Index
ELP - Environmental Leadership Program
EPA - United States Environmental Protection Agency
EPCRA - Emergency Planning and Community Right-to-Know Act
FIFRA - Federal Insecticide, Fungicide, and Rodenticide Act
FINDS - Facility Indexing System
HAPs - Hazardous Air Pollutants (CAA)
HSDB - Hazardous Substances Data Bank
IDEA - Integrated Data for Enforcement Analysis
LDR - Land Disposal Restrictions (RCRA)
LEPCs - Local Emergency Planning Committees
MACT - Maximum Achievable Control Technology (CAA)
MCLGs - Maximum Contaminant Level Goals
MCLs - Maximum Contaminant Levels
MEK - Methyl Ethyl Ketone
MSDSs - Material Safety Data Sheets
NAAQS - National Ambient Air Quality Standards (CAA)
NAFTA - North American Free Trade Agreement
NCDB - National Compliance Database (for TSCA, FIFRA, EPCRA)
NCP - National Oil and Hazardous Substances Pollution Contingency Plan
NEIC - National Enforcement Investigation Center
NESHAP - National Emission Standards for Hazardous Air Pollutants
NO_2 - Nitrogen Dioxide
NOV - Notice of Violation
NO_X - Nitrogen Oxides
NPDES - National Pollution Discharge Elimination System (CWA)
NPL - National Priorities List
NRC - National Response Center

NSPS -	New Source Performance Standards (CAA)
OAR -	Office of Air and Radiation
OECA -	Office of Enforcement and Compliance Assurance
OPA -	Oil Pollution Act
OPPTS -	Office of Prevention, Pesticides, and Toxic Substances
OSHA -	Occupational Safety and Health Administration
OSW -	Office of Solid Waste
OSWER -	Office of Solid Waste and Emergency Response
OW -	Office of Water
P2 -	Pollution Prevention
PCS -	Permit Compliance System (CWA Database)
POTW -	Publicly Owned Treatments Works
RCRA -	Resource Conservation and Recovery Act
RCRIS -	RCRA Information System
SARA -	Superfund Amendments and Reauthorization Act
SDWA -	Safe Drinking Water Act
SEPs -	Supplementary Environmental Projects
SERCs -	State Emergency Response Commissions
SIC -	Standard Industrial Classification
SO_2 -	Sulfur Dioxide
SO_X -	Sulfur Oxides
TOC -	Total Organic Carbon
TRI -	Toxic Release Inventory
TRIS -	Toxic Release Inventory System
TCRIS -	Toxic Chemical Release Inventory System
TSCA -	Toxic Substances Control Act
TSS -	Total Suspended Solids
UIC -	Underground Injection Control (SDWA)
UST -	Underground Storage Tanks (RCRA)
VOCs -	Volatile Organic Compounds

Page x intentionally left blank.

SHIPBUILDING AND REPAIR INDUSTRY
(SIC 3731)

I. INTRODUCTION TO THE SECTOR NOTEBOOK PROJECT

I.A. Summary of the Sector Notebook Project

Integrated environmental policies based upon comprehensive analysis of air, water, and land pollution are a logical supplement to traditional single-media approaches to environmental protection. Environmental regulatory agencies are beginning to embrace comprehensive, multi-statute solutions to facility permitting, enforcement and compliance assurance, education/ outreach, research, and regulatory development issues. The central concepts driving the new policy direction are that pollutant releases to each environmental medium (air, water, and land) affect each other, and that environmental strategies must actively identify and address these inter-relationships by designing policies for the "whole" facility. One way to achieve a whole facility focus is to design environmental policies for similar industrial facilities. By doing so, environmental concerns that are common to the manufacturing of similar products can be addressed in a comprehensive manner. Recognition of the need to develop the industrial “sector-based” approach within the EPA Office of Compliance led to the creation of this document.

The Sector Notebook Project was originally initiated by the Office of Compliance within the Office of Enforcement and Compliance Assurance (OECA) to provide its staff and managers with summary information for eighteen specific industrial sectors. As other EPA offices, states, the regulated community, environmental groups, and the public became interested in this project, the scope of the original project was expanded to its current form. The ability to design comprehensive, common sense environmental protection measures for specific industries is dependent on knowledge of several inter-related topics. For the purposes of this project, the key elements chosen for inclusion are: general industry information (economic and geographic); a description of industrial processes; pollution outputs; pollution prevention opportunities; Federal statutory and regulatory framework; compliance history; and a description of partnerships that have been formed between regulatory agencies, the regulated community, and the public.

For any given industry, each topic listed above could alone be the subject of a lengthy volume. However, in order to produce a manageable document, this project focuses on providing summary information for each topic. This format provides the reader with a synopsis of each issue, and references where more in-depth information is available. Text within each profile was researched from a variety of sources, and was usually condensed from more detailed sources pertaining to specific topics. This approach allows for a wide coverage of activities that can be further explored based upon the citations and references listed at the end of this profile. As a check on the information included, each notebook went through an external review process. The Office of Compliance appreciates the efforts of all those that participated in this process and enabled us to develop more complete, accurate and up-to-date summaries. Many of those who reviewed this notebook are listed as contacts in Section IX and may be sources of additional information. The individuals and groups on this list do not necessarily concur with all statements within this notebook.

I.B. Additional Information

Providing Comments

OECA's Office of Compliance plans to periodically review and update the notebooks and will make these updates available both in hard copy and electronically. If you have any comments on the existing notebook, or if you would like to provide additional information, please send a hard copy and computer disk to the EPA Office of Compliance, Sector Notebook Project, 401 M St., SW (2223-A), Washington, DC 20460. Comments can also be uploaded to the Enviroene World Wide Web for general access to all users of the system. Follow instructions in Appendix A for accessing this system. Once you have logged in, procedures for uploading text are available from the on-line Enviroene Help System.

Adapting Notebooks to Particular Needs

The scope of the industry sector described in this notebook approximates the national occurrence of facility types within the sector. In many instances, industries within specific geographic regions or states may have unique characteristics that are not fully captured in these profiles. The Office of Compliance encourages state and local environmental agencies and other groups to supplement or re-package the information included in this notebook to include more specific industrial and regulatory information that may be available. Additionally, interested states may want to supplement the "Summary of Applicable Federal Statutes and Regulations" section with state and local requirements. Compliance or technical assistance providers may also want to develop the "Pollution Prevention" section in more detail. Please contact the appropriate specialist listed on the opening page of this notebook if your office is interested in assisting us in the further development of the information or policies addressed within this volume. If you are interested in assisting in the development of new notebooks for sectors not covered in the original eighteen, please contact the Office of Compliance at 202-564-2395.

II. INTRODUCTION TO THE SHIPBUILDING AND REPAIR INDUSTRY

This section provides background information on the size, geographic distribution, employment, production, sales, and economic condition of the ship building and repair industry. Facilities described within this document are described in terms of their Standard Industrial Classification (SIC) codes.

II.A. Introduction, Background, and Scope of the Notebook

The shipbuilding and repair industry builds and repairs ships, barges, and other large vessels, whether self-propelled or towed by other craft. The industry also includes the conversion and alteration of ships and the manufacture of offshore oil and gas well drilling and production platforms. The shipbuilding and repair industry described in this notebook is categorized by the Office of Management and Budget (OMB) under the Standard Industrial Classification (SIC) code 3731. This notebook does not cover the related sector SIC 3732 Boat Building and Repairing. The boat building and repair industry is engaged in the manufacturing and repairing of smaller non-ocean going vessels primarily used for recreation, fishing, and personnel transport. OMB is in the process of changing the SIC code system to a system based on similar production processes called the North American Industrial Classification System (NAICS). (In the NAIC system, shipbuilding and repair facilities are all classified as NAIC 336611.)

II.B. Characterization of the Shipbuilding and Repair Industry

Shipyards, or facilities that build and/or repair ships, operate on a job basis. With the exception of about nine U.S. Navy owned shipyards (which are not included in SIC 3731), the U.S. shipbuilding and repair industry is privately owned. Unlike most other industries, each year only a small number of valuable orders are received that often take years to fill. Orders for ships and ship repairs are primarily placed by companies or the federal government. Companies that place orders often include commercial shipping companies, passenger and cruise companies, ferry companies, petrochemical companies, commercial fishing companies, and towing and tugboat companies. The principal federal government agencies placing shipbuilding and repair orders include the Naval Sea Systems Command, the Military Sealift Command, the Army Corps of Engineers, the U.S. Coast Guard, the National Oceanic and Atmospheric Administration, the National Science Foundation, and the Maritime Administration.

II.B.1. Product Characterization

Shipyards are often categorized into a few basic subdivisions either by type of operations (shipbuilding or ship repairing), by type of ship (commercial or military), and shipbuilding or repairing capacity (first-tier or second-tier).

Ships themselves are often classified by their basic dimensions, weight (displacement), load-carrying capacity (deadweight), or their intended service. In the U.S., there are considerable differences between shipyard operations when constructing ships for commercial purposes and when constructing ships for the military.

Commercial Ships

An important difference between commercial ships and military ships is that the commercial ship market is much more cost competitive. Unlike the military market, the commercial ship market must also compete internationally. The cost of building and maintaining a ship must be low enough such that the owners can make a reasonable profit. This has a significant impact on the manner in which commercial ships are built and repaired. The intense global competition in this industry is the main reason that since World War II, U.S. shipyards have produced relatively few commercial ships. In this regard, since 1981 the U.S. shipyards received less than one percent of all commercial orders for large ocean going vessels in the world, and no commercial orders for large ocean going cruise ships (ASA, 1997).

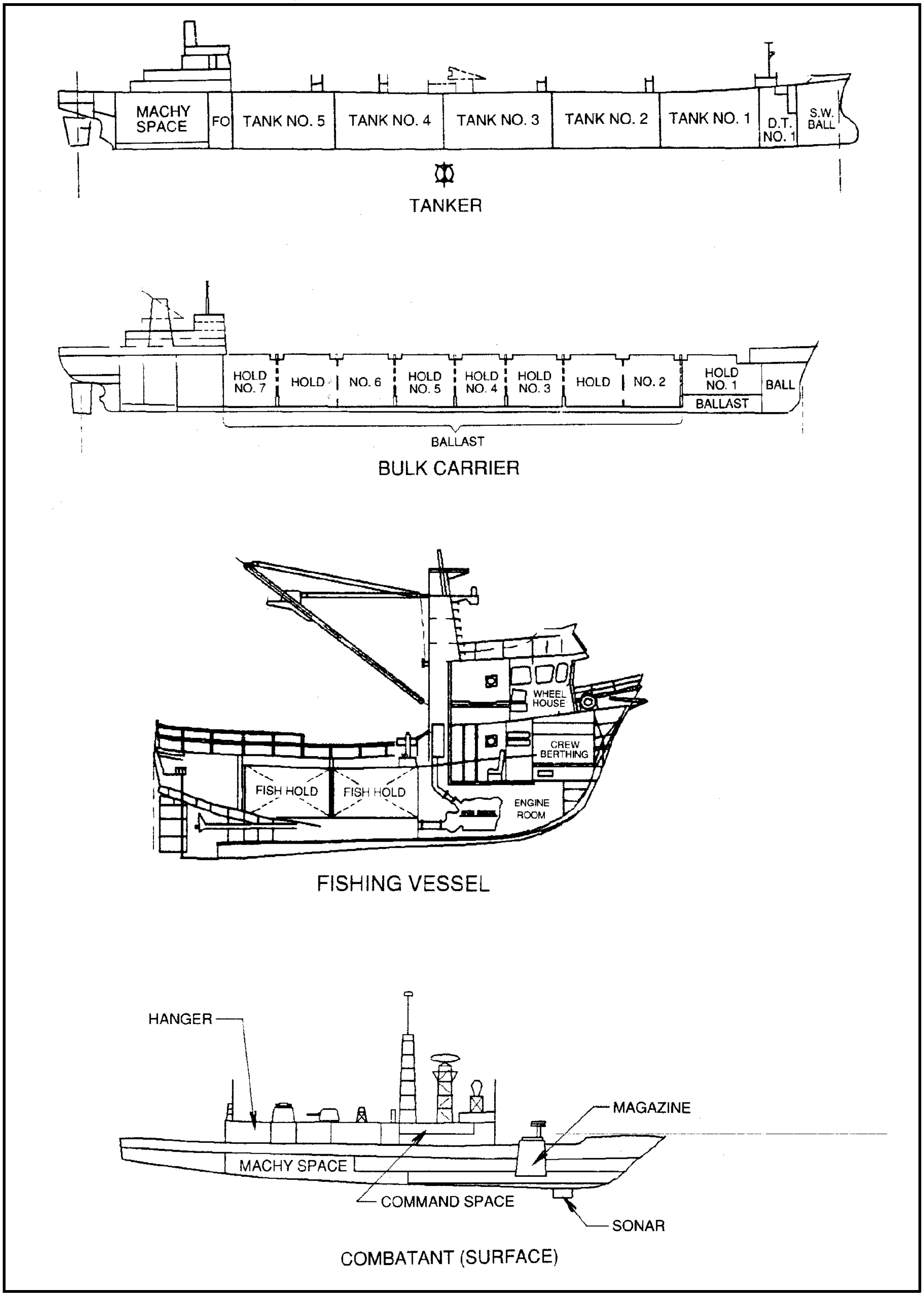
Commercial ships can be subdivided into a number of classes based on their intended use. Commercial ship classes include dry cargo ships, tankers, bulk carriers, passenger ships, fishing vessels, industrial vessels, and others (Storch et al., 1995). Dry cargo ships include break bulk, container, and roll-on/roll-off types. Profiles of a number of ship types are shown in Figure 1.

Military Ships

Military ship orders have been the mainstay of the industry for many years. The military ship market differs from the commercial market in that the major market drivers are agency budgets as set by government policy.

The military ship market can be divided into combatant ships and ships that are ordered by the government, but are built and maintained to commercial standards rather than military standards. (Storch et al., 1995) Combatant ships are primarily ordered by the U.S. Navy and include surface combatants, submarines, aircraft carriers, and auxiliaries. Government owned non-combatant ships are mainly purchased by the Maritime Administration's National Defense Reserve Fleet (NDRF) and the Navy's Military Sealift Command (MSC). Other government agencies that purchase non-combatant ships are the Army Corp of Engineers, National Oceanic and Atmospheric Administration, and the National Science Foundation. Such ships often include cargo ships, transport ships, roll on/roll off ships, crane ships, tankers, patrol ships, and ice breakers.

Figure 1: Profiles of Ship Types



Source: Adapted from *Ship Production*, Storch, et. al., 1995.

Ship Repairing

Ship repair operations include repainting, overhauls, ship conversions, and alterations. Almost all shipyards that construct new ships also do major ship repairs. In addition, about 200 shipyards concentrate solely on ship repairing and do not have the necessary facilities to construct ships (Storch et. al., 1995). Only about 31 shipyards have “major dry-docking facilities” capable of removing ships over 122 meters in length from the water (MARAD, 1995). Dry-docking facilities, or “full service” repair yards, allow repairs and maintenance below a ship’s water line. The remaining repair yards can either dry-dock vessels under 122 meters or have no dry-docking facilities. Shipyards with no dry-docking facilities, called topside yards, perform above-water ship and barge repairs. Such facilities generally employ fewer than 100 people and are often capable of transporting workers and materials to the ship (Storch et al., 1995).

First and Second-Tier Shipyards

U.S. shipyards are also classified by MARAD as either first-tier shipyards or second-tier shipyards. First-tier shipyards make up the “U.S. major shipbuilding base” (MSB). As defined by MARAD and the Department of Transportation in “Report on Survey of U.S. Shipbuilding and Repair Facilities,” 1995, the MSB is comprised of privately owned shipyards that are open and have at least one shipbuilding position capable of accommodating a vessel of 122 meters (383 feet) or more. With few exceptions, these shipyards are also major repair facilities with drydocking capabilities (U.S. Industrial Outlook, 1994). In 1996 there were 16 of these major shipbuilding facilities in the U.S.

Second-tier shipyards are comprised of the many small and medium-size shipyards that construct and repair smaller vessels (under 122 meters) such as military and non-military patrol boats, fire and rescue vessels, casino boats, water taxis, tug and towboats, off-shore crew and supply boats, ferries, fishing boats, and shallow draft barges (MARAD, 1996). A number of second-tier shipyards are also able to make topside repairs to ships over 122 meters in length.

II.B.2. Industry Size and Geographic Distribution

According to the *1992 Census of Manufacturers* data (the most recent Census data available), there were approximately 598 shipbuilding and repairing yards under SIC code 3731. The payroll for this year totaled \$3.6 billion for a workforce of 118,000 employees, and value of shipments totaled \$10.6 billion. Based on the Census of Manufacturers data, the industry is very labor intensive. The value of shipments per employee (a measure of labor intensiveness) is \$90,000, which is about one third that of the steel manufacturing industry ($245,000 per employee) and only five percent that of the petroleum refining industry ($1.8 million per employee).

According to the *Census of Manufacturers*, most shipyards are small. About 72 percent of the shipyards employ fewer than 50 people in 1992 (see Table 1). It is the relatively few (but large) shipyards, however, that account for the majority of the industry's employment and sales. Less than five percent of the shipyards account for almost 80 percent of the industry's employment and sales.

Table 1: Facility Size Distribution for the Shipbuilding and Repair Industry

Employees per Facility	**Facilities**		**Employees**	
	Number of Facilities	Percentage of Facilities	Number of Employees	Percentage of Employees
1-9	230	38%	900	1%
10-49	203	34%	4,600	4%
50-249	113	19%	12,900	11%
250-499	25	4%	8,200	7%
500-2499	21	4%	17,100	14%
2500 or more	6	1%	74,600	63%
Total	598	100%	118,300	100%

Source: U.S. Department of Commerce, Census of Manufacturers, 1992.

Geographic Distribution

The geographic distribution of the shipbuilding and repair industry is concentrated on the coasts. Other important areas are the southern Mississippi River and Great Lakes regions. According to the *1992 U.S. Census of Manufacturers*, there are shipyards in 24 states. The top states in order are: Florida, California, Louisiana, Texas, Washington, and Virginia. Together, these states account for about 56 percent of U.S. shipyards. Figure 2 shows the U.S. distribution of facilities based on data from the Census of Manufacturers.

Figure 2: Geographic Distribution of Shipyards

Source: U.S. Census of Manufacturers, 1992.

Dun & Bradstreet's *Million Dollar Directory*, compiles financial data on U.S. companies including those operating within the shipbuilding and repair industry. Dun & Bradstreet ranks U.S. companies, whether they are a parent company, subsidiary or division, by sales volume within their assigned 4-digit SIC code. Readers should note that: (1) companies are assigned a 4-digit SIC that resembles their principal industry most closely; and (2) sales figures include total company sales, including subsidiaries and operations (possibly not related to shipbuilding and repair). Additional sources of company specific financial information include Standard & Poor's *Stock Report Services*, *Ward's Business Directory of U.S. Private and Public Companies*, Moody's Manuals, and annual reports.

Table 2: Top U.S. Companies with Shipbuilding and Repair Operations

Rank[a]	Company[b]	1996 Sales (millions of dollars)
1	Newport News Shipbuilding and Dry Dock Co. Newport News, VA	1,756
2	Ingalls Shipbuilding Inc. - Pascagoula, MS	1,125
3	General Dynamics Corp. (Electric Boat) - Groton, CT	980
4	Bath Iron Works Corp. - Bath, ME	850
5	Avondale Industries Inc., Shipyards Division New Orleans, LA	576
6	National Steel and Shipbuilding Co. (NASSCO) San Diego, CA	500
7	Trinity Marine Group - Gulfport, MS	400
8	Norfolk Shipbuilding and Drydock Corp. - Norfolk, VA	212
9	American Commercial Marine Service Co. - Jeffersonville, IN	166
10	Atlantic Marine - Jacksonville, FL	121

Note: [a]Not all sales can be attributed to the companies' shipbuilding and repair operations.
[b] Companies shown listed SIC 3731.

Source: *Dunn & Bradstreet's Million Dollar Directory - 1996.*

II.B.3. Economic Trends

General Economic Health

In general, the U.S. shipbuilding and repair industry is in a depressed state. At its height in the mid-1970s, the industry held a significant portion of the international commercial market while maintaining its ability to supply all military orders. Since then, new ship construction, the number of shipbuilding and repair yards, and overall industry employment have decreased sharply. The decline has been especially severe in the construction of commercial vessels at first tier shipyards which fell from about 77 ships (1,000 gross tons or more) per year in the mid-1970s to only about eight ships total through the late 1980s and early 1990s. In the 1980s, the industry's loss of the commercial market share was somewhat offset by a substantial increase in military ship orders. Following the naval expansion, however, the industry entered the 1990s with a much smaller military market and a negligible share of the commercial market.

The second tier shipyards and the ship repairing segment of the industry has also suffered in recent decades; however, its decline has not been as drastic. The second tier shipyards, comprised of small and medium size facilities, were able to keep much of their mainly commercial market share. These shipyards build vessels used on the inland and coastal waterways which by law must be built in the U.S.

The U.S. shipbuilding and repairing industry's loss of the commercial shipbuilding market has been attributed to a number of factors. First, a world wide shipbuilding boom in the 1970s created a large quantity of surplus tonnage which suppressed demand for years. Another significant factor reducing U.S. shipbuilding and repair industry's ability to compete internationally are the substantial subsidies that many nations provide to their domestic shipbuilding and repair industries. Also, until 1980, over 40 percent of U.S.-built merchant ships received Construction Differential Subsidies (CDS) based on the difference between foreign and domestic shipbuilding costs. The program was eliminated in 1981, further reducing the industry's competitiveness.

Another trend in the industry has been a movement toward consolidation. In recent years many shipyards have been closed or purchased by larger ship building and repair companies.

Government Influences

The U.S. shipbuilding and repair industry is highly dependent on the Federal Government, its primary market, for its continued existence. Direct purchases of military ships and military ship repair services by the Federal Government account for about 80 percent of the industry's sales (Census of Manufacturers, 1992). In addition, the industry receives a small amount of support through a few federal tax incentives and financing assistance programs.

MARAD provides assistance to U.S. ship owners through the Federal Ship Mortgage Insurance (Title XI) and Capital Construction Fund programs. Under Title XI, the Federal Government guarantees repayment of private sector mortgage obligations for operators that purchase ships from U.S. shipyards. Although the Capital Construction Fund has not been funded in recent years, in the past it has allowed operators to establish tax-deferred funds for procuring new or reconstructed vessels from U.S. shipyards (U.S. Industrial Outlook, 1994). Another program, MARITECH, is jointly funded by the Federal Government and industry and is administered by the Department of Defense's Advanced Research Projects Agency (ARPA), in collaboration with MARAD. MARITECH provides matching Government funds to encourage the shipbuilding industry to direct and lead in the development and application of advanced technology to improve its competitiveness and to preserve its industrial base. (For more information on MARITECH, see Section VIII.A.)

Such outside support is not unique to the U.S. Worldwide, many nations provide substantial subsidies to their shipbuilding and repair industries. The governments of most trading nations support their domestic industries because they believe that it is in their best interest economically and militarily. Maintaining a shipbuilding industrial base helps to safeguard a nation's control over getting its products to foreign markets, and ensures that it will have the means to replace its merchant or naval fleets in a time of national emergency. As a result of these external influences, the industry does not behave according to the simple economic supply and demand model. Rather, the policies of national governments in conjunction with economic forces dictate economic activity in this sector.

Like many other nations, the U.S. has a policy of maintaining a shipbuilding and repair industrial base that can be expanded in time of war (Storch, et al., 1995). National policy, therefore, will continue to be the primary factor influencing the industry's economic trends in the U.S.

Domestic Market

The military still is, and will continue to be, the primary source of work for the industry. However, the Navy's new ship procurement has sharply declined since the accelerated Navy ship construction in the 1980s. This work is expected to continue to decline at least through the remainder of the 1990s. Some industry analysts predict that a number of the first tier shipyards, which fill most of the military orders, will close in coming years.

While military shipbuilding is on the decline, the forecast for the commercial sector is more promising. Domestic demand for commercial shipbuilding and repair has increased dramatically in recent years and is expected to continue to increase throughout the 1990s. There have been significant increases in barge construction in recent years. In 1996, 1,070 hopper barges were delivered by U.S. shipyards, more than double the number delivered in 1995. This number is expected to grow to over 1,500 in 1997. Demand is also expected to be particularly high for tankers; especially for new double-hull tankers in response to the 1990 Oil Pollution Act requirements.

International Market

Currently, the U.S. holds less than one half of one percent of the world market share of commercial shipbuilding and repair. South Korea and Japan currently dominate the world market. Each holds about 30 percent of the gross tonnage of merchant ships on order. Germany, Poland, Italy, and China each hold between four and five percent of the commercial market. However, a number of major commercial ship orders were received by first and second tier shipyards in 1995 and 1996. The chief driving forces for this increase in U.S. commercial ship production is a general increase in worldwide demand stemming from an aging merchant fleet and an improving global economy. The elevated demand is expected to continue over the next three to five years.

Through the OECD in December 1994, an agreement was reached by the Commission of the European Communities, and the Governments of Finland, Japan, South Korea, Norway, Sweden and the United States to establish more normal competitive conditions in the shipbuilding industry. The agreement is expected to remove government support and unfair pricing practices in the industry. If and when this agreement is implemented, it is expected to have a positive impact on the world market by discouraging "ship dumping" practices that are believed to have been damaging shipbuilders. It is hoped that the agreement will also bring to light the actual economic advantage and competitiveness of the various countries and individual ship builders. In addition, the shipowners will no longer be able to buy ships at subsidized or dumped prices reducing the likelihood of speculative buying.

Recognizing the unique need for the Administration, Congress and the shipbuilding industry to work together in order for the U.S. to become competitive once again in the international shipbuilding market, President Clinton submitted a Report to Congress entitled "Strengthening America's Shipyards: A Plan for Competing in the International Market." In that report, the President outlined a number of steps to be taken "to ensure a successful transition to a competitive industry in a truly competitive marketplace." The Administration's five step plan included:

- Ensuring Fair International Competition
- Improving Competitiveness
- Eliminating Unnecessary Government Regulation
- Financing Ship Sales Through Title XI Loan Guarantees, and
- Assisting International Marketing.

III. INDUSTRIAL PROCESS DESCRIPTION

This section describes the major industrial processes within the shipbuilding and repair industry, including the materials and equipment used and the processes employed. The section is designed for those interested in gaining a general understanding of the industry, and for those interested in the inter-relationship between the industrial process and the topics described in subsequent sections of this profile -- pollutant outputs, pollution prevention opportunities, and Federal regulations. This section does not attempt to replicate published engineering information that is available for this industry. Refer to Section IX for a list of resource materials and contacts that are available.

This section specifically contains a description of commonly used production processes, associated raw materials, the by-products produced or released, and the materials either recycled or transferred off-site. This discussion, coupled with schematic drawings of the identified processes, provide a concise description of where wastes may be produced in the process. This section also describes the potential fate (via air, water, and soil pathways) of these waste products.

III.A. Industrial Processes in the Shipbuilding and Repair Industry

The shipbuilding and repair industry has characteristics of both a manufacturing industry and the construction industry. The industry uses and produces a wide variety of manufactured components in addition to basic construction materials. As with the construction industry, shipbuilding and repair requires many workers with many different skills all working in an established organization structure.

New ship construction and ship repairing have many industrial processes in common. They both apply of essentially the same manufacturing practices, processes, facilities, and support shops. Both ship repair and new construction work require highly skilled labor because many of the operations (especially in ship repair) have limited potential for automation. Both require excellent planning, engineering, and interdepartmental communications. New ship construction, however, generally requires a greater amount of organization because of the size of the workforce, size of the workload, number of parts, and the complexity of the communications (e.g., production plans and schedules) surrounding the shipbuilding work-flow (NSRP, 1993).

III.A.1. Shipyard Layout

Shipbuilding and repair facilities are generally made up of several specific facilities laid out to facilitate the flow of materials and assemblies. Most shipyards were built prior to the Second World War. Changes in shipyard layout were made piecemeal, responding to advances in technology, demands for different types of ships, and availability of land and waterfront. As a result, there is no typical shipyard layout. There are, however, a number of specific facilities that are common to most large shipyards. These facilities include: drydocks, shipbuilding positions, piers and berthing positions, workshops (e.g., machine, electrical, pipe, assembly, paint and blast, carpenter, and sheet metal shops), work areas (steel storage, platen lines, and construction areas), warehouses, and offices. A shipyard layout containing many of these facilities is shown in Figure 3.

III.A.2. Docking and Launching Facilities

There are few shipyards that have the capability to construct or repair vessels under cover; in most cases shipbuilding and repair are done largely out of doors. Much of this work is done over, in, under, or around water, which can inadvertently receive a portion of shipyard pollutant outputs. The docking facilities, or the mechanisms used to remove ships from the water for repair or to construct and launch ships, can affect waste generation and management.

Ships can be either wet-docked or drydocked. A wet-dock or berth is a pier or a wet slip position that a ship can dock next to and tie up. A ship that has its entire hull exposed to the atmosphere is said to be drydocked. A number of different drydocking and launching facilities exist including building ways, floating drydocks, graving docks, and marine railways.

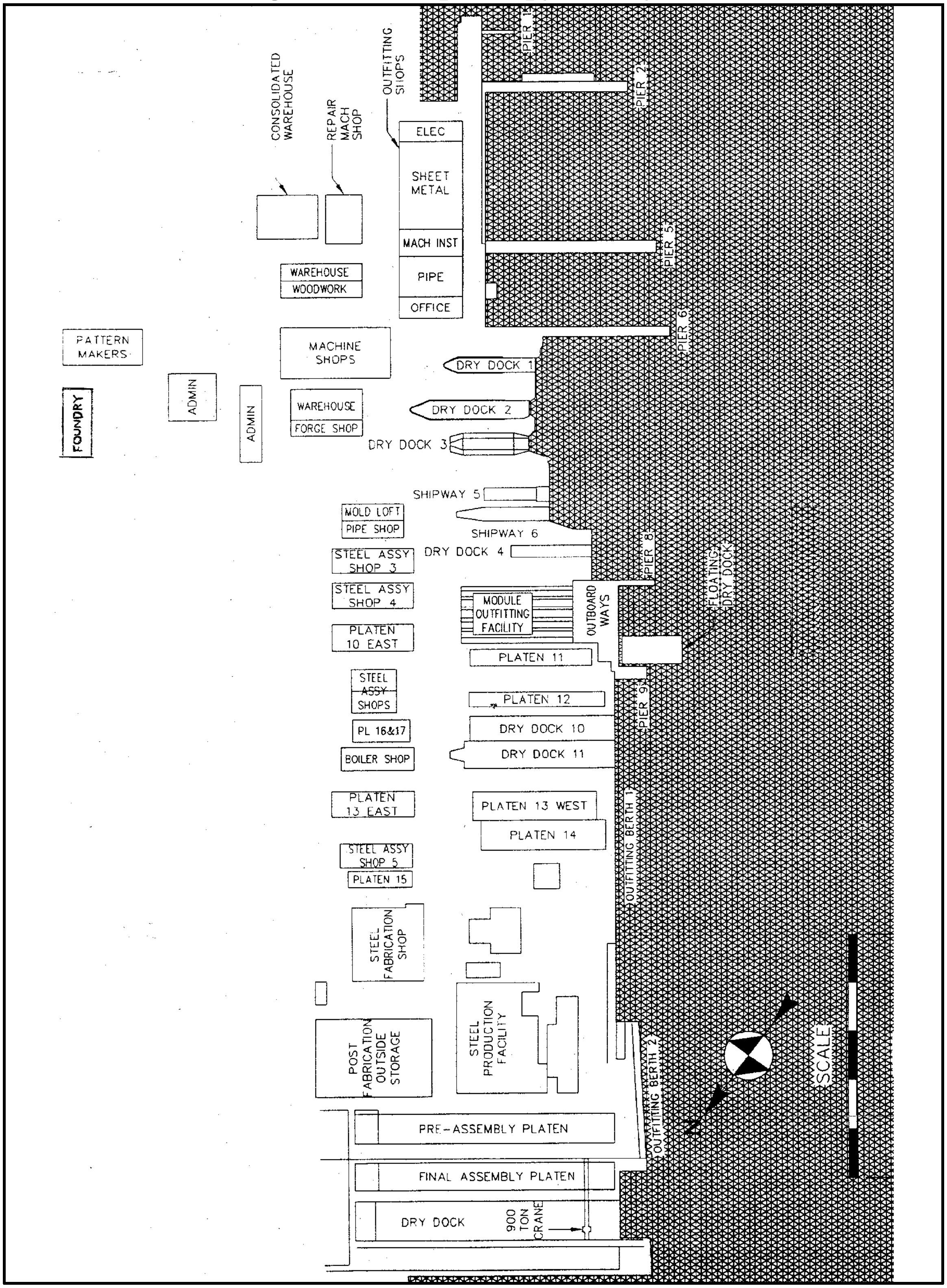
Building Ways

Building ways are used only for building ships and releasing them into the adjacent waters. New ships are constructed and launched from one of two main types of building ways: longitudinal end launch ways and side launch ways (NSRP, 1993).

Floating Drydocks

Floating drydocks are floating vessels secured to land that have the ability to be lowered under the water's surface in order to raise ships above the water surface. Floating drydocks are generally used for ship repair, but in some cases ship construction is performed. When the drydock is submerged by filling ballast tanks with water, ships are positioned over bilge and keel blocks located on the deck of the drydock. The ship's position over the drydock is maintained while the ballast tanks are pumped out, which raises the dock and the ship above the water surface (NSRP, 1993).

Figure 3: Example Shipyard Layout



Source: Maritime Administration, *Report on Survey of U.S. Shipbuilding and Repair Facilities*, 1995.

Graving Docks

Graving docks are man-made rectangular bays where water can be let in and pumped out. Ships are floated into the dock area when the dock is full of water. Water-tight gates are closed behind the ship and the water is pumped from inside the dock area to the outside adjacent waters. Large pumping systems are typically used to remove all but a few inches of the water. Graving docks usually have a sloping dock floor which directs the water to channels leading to smaller pumps which empty the final few inches of water as well as any rain or water runoff which enters the dock (NSRP, 1993).

Marine Railways

Marine railways have the ability to retrieve and launch ships. They are similar to end-launch building ways, but usually much smaller. Marine railways essentially consist of a rail-car platform and a set of railroad tracks. The rails are secured to an inclined cement slab that runs the full length of the way and into the water to a depth necessary for docking ships. Motor and pulley systems are located at the head of marine railways to pull the rail-car platform and ship from the water (NSRP, 1993).

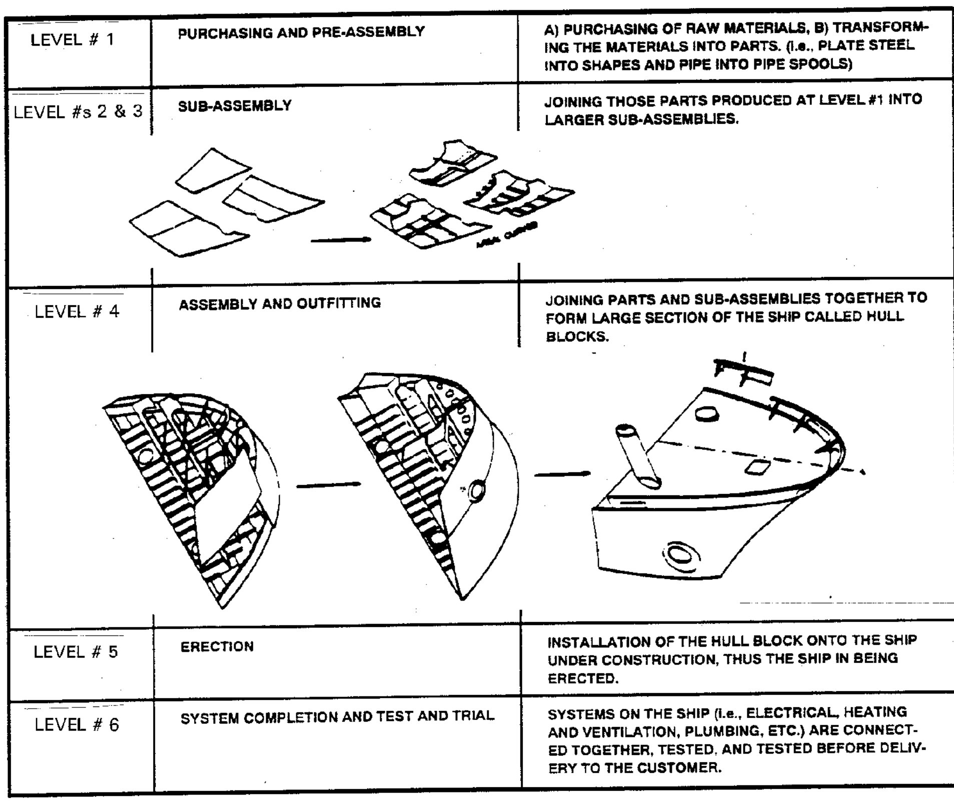
III.A.3. Ship Construction Processes

Most new ship construction projects are carried out using zone-oriented methods, such as the hull block construction method (HBCM). In HBCM, the ship structure is physically divided into a number of blocks. The definition of hull blocks has an enormous impact on the efficiency of the ship construction. Therefore, blocks are carefully designed to minimize work and to avoid scheduling problems. Blocks are constructed and pieced together in five general manufacturing levels. Figure 4 summarizes the various manufacturing levels.

The first level involves the purchasing and handling of raw materials and fabricating these materials into the most basic parts. The primary raw materials include steel plates, bars, and structural members. Parts fabrication or pre-assembling operations often involve cutting, shaping, bending, machining, blasting, and painting of these materials. Fabricated parts include steel plates and steel members used as structural parts, machined parts, piping, ventilation ducts, electrical components (motors, lights, transformers, gauges, etc.), and a wide variety of other miscellaneous parts. Parts fabrication is carried out throughout the shipyard in a number of different shops and work areas depending on the specific raw materials being handled (see Section III.A.7 for a description of typical operations conducted in shipyard shops).

Level 2 of new ship construction involves the joining of different fabricated parts from Level 1 into assembled parts. In the third level of manufacturing the fabricated and/or assembled parts are fitted together into a sub-block assembly which are in turn fitted together in Level 4 to form blocks. Blocks are three dimensional sections of the ship and are the largest sections of the ship to be assembled away from the erection site. Blocks are designed to be stable configurations that do not require temporary support or reinforcement. Often, at least one side of a block forms part of the outside hull of the ship. Blocks are built and transported through the shipyard and welded together at a building position where the ship is erected. The size of the blocks that a shipyard can build is dependent on the shipyard capacity to assemble, transport, and lift the blocks and units onto the ship under construction. In Level 5 the ship is erected from the blocks (Storch, 1995).

Figure 4: General Ship Manufacturing Levels



Source: Adapted from NSRP, *Introduction to Production Processes and Facilities in the Steel Shipbuilding and Repair Industry* , 1993.

Another important aspect of ship construction is outfitting. Outfitting, which involves the fabrication and installation of all the parts of a ship that are not structural in nature, is carried out concurrently with the hull construction. Outfit is comprised of the ship's plumbing, derricks, masts, engines, pumps, ventilation ducts, electrical cable, stairs, doors, ladders, and other equipment. The basic raw materials include pipes, sheet metal, electrical components, and machinery. A zone-oriented method is typically used to assemble the parts that form major machinery spaces onboard the ship including engine rooms, pump rooms, and auxiliary machinery spaces. Parts or fittings can be assembled onboard the ship during hull erection, on the blocks or subblocks, or independent of the hull structure in units of similar parts (NSRP, 1993).

III.A.4. Major Production Facilities

Most shipbuilding yards have in common the following major facilities, work areas, or specialized equipment.

Prime Line

The prime line is a large machine that blasts and primes (paints) raw steel sheets, preparing them for production. Steel sheets, parts, and shapes enter one end of the prime line, go through a blasting section, then through a priming section. The primer is referred to as construction primer, and is used to prevent corrosion during the production process. Section III.A.9 discusses surface preparation and coating operations in more detail (NSRP, 1993).

Panel Lines

Panel lines typically consist of motor driven conveyors and rollers used to move large steel plates together for joining. The use of panel lines introduced manufacturing production line techniques into the steel shipbuilding industry. Joining of plates involves the welding of the seams either on one side or two sides. Two sided welding requires the panel line to be capable of turning the steel plates over after one-side is welded. Vertical stiffeners are also welded on the panel line often using automated welding machines. After welding, excess steel is cut off using gas cutting equipment. Panel assemblies are typically moved through the line with the aid of magnetic cranes (NSRP, 1993).

Platen Lines

The platen lines (or platens) are the area in the shipyard where blocks are assembled. Therefore, platens form assembly lines where the steel structures of construction blocks are fabricated. Sub-assemblies from the panel line and plate shop are brought together at the platen and assembled into blocks. The platen mainly provides locations for sub-assembly construction, block layout, tack-welding, and final weld out. The platen lines are serviced by welding and steel cutting equipment and cranes for materials movement (NSRP, 1993).

Rolls

Rolls are large facilities that bend and shape steel plates into curved surface plates for the curved portion of the hull. Rolls consist of large cylindrical steel shafts and a motor drive. Rolls vary greatly in size and technology from shipyard to shipyard. Some of the newer rolls are computer controlled, while the older machines are manually operated (NSRP, 1993).

Pin Jigs

Pin jigs are platen lines used to assemble the curved blocks that form the outside of the hull's curved surface. The pin jig is simply a series of vertical screw jacks that support curved blocks during construction. A pin jig is set up specifically for the curved block under construction. The jig heights are determined from the ship's engineering drawings and plans (NSRP, 1993).

Rotary Tables

Rotary tables are facilities that hull blocks are set into and which mechanically rotate the block. The ability to easily rotate an entire block in a single location reduces the number of time-consuming crane lifts that would otherwise be needed. Rotary tables also exploit the increased efficiencies experienced when workers are able to weld on a vertical line (down hand). Down hand welding provides a higher quality weld with higher efficiency rates. Turn tables are also used for outfitting materials on the block because of easier access to outfitting locations (NSRP, 1993).

Materials Handling

Materials handling is an important aspect of efficient shipbuilding. Considerable coordination is needed between materials delivery and the production schedule. Materials need to be delivered to the proper location in the shipyard at the proper time to be installed on the construction block. Typical materials handling equipment includes conveyors, cranes, industrial vehicles (e.g., forklifts, flatbeds, carts, special lift vehicles, etc.), and containers (NSRP, 1993).

III.A.5. Welding

The structural framework of most ships is constructed of various grades of mild and high strength steel. Aluminum and other nonferrous materials are used for some superstructures (deck-houses) and other areas requiring specific corrosion resistance and structural requirements. However, other common materials such as stainless steel, galvanized steel, and copper nickel alloys, are used in far less quantities than steel (ILO, 1996).

The primary raw material for ship construction is steel plate. Steel plates are typically cut to the desired size by automatic burners before being welded together to form the structural components of the vessel.

Shipyard welding processes are performed at nearly every location in the shipyard. The process involves joining metals by bringing the adjoining surfaces to extremely high temperatures to be fused together with a molten filler material. An electric arc or gas flame are used to heat the edges of the joint, permitting them to fuse with molten weld fill metal in the form of an electrode, wire, or rod. There are many different welding techniques used by the industry. Most welding techniques can be classified as either electric arc or gas welding, with electric arc being the most common (ILO, 1996).

An important factor impacting the strength of welds is arc shielding, isolating the molten metal weld pool from the atmosphere. At the extremely high temperatures used in welding, the molten metal reacts rapidly with oxygen and nitrogen in the atmosphere which decreases the weld strength. To protect against this weld impurity and ensure weld quality, shielding from the atmosphere is required. In most welding processes, shielding is accomplished by addition of a flux, a gas, or a combination of the two. Where a flux material is used, gases generated by vaporization and chemical reaction at the electrode tip result in a combination of flux and gas shielding that protect the weld from the atmosphere. The various types of electric arc welding (shielded metal arc, submerged arc, gas metal arc, gas tungsten arc, flux core arc, and plasma-arc) all use different methods to accomplish arc shielding (ILO, 1996).

III.A.6. Ship Repairing Processes

Ship repair generally includes all ship conversions, overhauls, maintenance programs, major damage repairs, and minor equipment repairs. Although specific repair methods vary from job to job, many of the operations are identical to new ship construction operations. Repair operations, however, are typically on a smaller scale and are performed at a faster pace. Jobs can last anywhere from one day to over a year. Repair jobs often have severe time constraints requiring work to be completed as quickly as possible in order to get the ships back in service. In many cases, piping, ventilation, electrical, and other machinery are prefabricated prior to the ship's arrival. Often, repair jobs are an emergency situation with very little warning, which makes ship repair a fast moving and unpredictable environment. Typical maintenance and repair operations include:

- Blasting and repainting the ship's hull, freeboard, superstructure, and interior tanks and work areas

- Major rebuilding and installation of machinery such as diesel engines, turbines, generators, pump stations, etc.

- Systems overhauls, maintenance, and installation (e.g., piping system flushing, testing, and installation)

- System replacement and new installation of systems such as navigational systems, combat systems, communication systems, updated piping systems, etc.

- Propeller and rudder repairs, modification, and alignment

- Creation of new machinery spaces through cut outs of the existing steel structure and the addition of new walls, stiffeners, vertical, webbing, etc.

In addition, some larger shipyards are capable of large repair and conversion projects that could include: converting supply ships to hospital ships, cutting a ship in half and installing a new section to lengthen the ship, replacing segments of a ship that has run aground, completing rip-out, structural reconfiguration and outfitting of combat systems, major remodeling of ships' interiors or exteriors (NSRP, 1993).

III.A.7. Support Shops and Services

Shipyards typically have a number of support shops that either process specific raw materials (e.g., pipes, electric, sheet metal, machinery, plates, paint, etc.) or provide specialty services (e.g., carpentry, maintenance, materials transporting, warehousing, etc.). In many ways, support shops are small manufacturers producing goods to support the production effort (NSRP, 1993). Common shipbuilding and repair yard support shops and services are described below.

Pipe Shop

The pipe shop is responsible for manufacturing and assembling piping systems. Piping systems are the largest outfitting task in shipbuilding. Small pipe sections known as "pipe spools" are assembled in the pipe shop and transported to the stages of construction (i.e., assembly, on-block, on-unit, and on-board). Pipe spools are shaped and manufactured per engineering design, are scheduled for construction, and sent to the various stages for installation. Many pipe shops will tag the spools to identify the location for installation on the block and ship. A typical ship may have anywhere from 10,000 to 25,000 pipe spools. Some of the processes in the pipe shop include: pipe welding, pipe bending, flux removal, grit-blast, pickling, painting, galvanizing, and pressure testing. Some of the equipment used by the pipe shop are as follows: pipe welders, lathes, pipe cutting saws, shears, grinders, chippers, hole cutters, pipe benders, pickling tanks, and transportation equipment (NSRP, 1993).

Machine Shop

The machine shop serves the entire shipyard's machining needs though the exact functions of the shipyard machine shops vary throughout the shipbuilding industry. Shipyard machine shops perform functions ranging from rebuilding pumps to turning 25 foot long propeller drive shafts on lathes. Equipment in the machine shop consists of: end mills, lathes, drill presses, milling machines, band saws, large presses, work tables, and cleaning tanks (NSRP, 1993).

Sheet Metal Shop

The sheet metal shop is generally responsible for fabricating and installing ventilation ducting and vent spools. Using engineering drawings and special sheet metal tools this shop produces ventilation systems for new construction, as well as repair work. The shop cuts, shapes, bends, welds, stamps, paints, and performs a variety of manufacturing operations for ship ventilation systems. Many sheet metal shops are also responsible for assembling large ducting fans and heating and air conditioning components. Sheet metal workers perform the installation of the ducting in various stages of construction such as on-block, on-unit, onboard (NSRP, 1993).

Electrical Shop

Electrical shops in the shipyard perform a variety of functions throughout the industry. In many cases, the electrical shop installs, rebuilds, builds, and tests electrical components (e.g., motors, lights, transformers, gauges, etc.). The electrical shop electricians also install the electrical equipment on the ship either on-block or onboard. On-block is where the electrical parts are installed and onboard is where cables are routed throughout the ship connecting the electrical systems together. Electric shops generally have plating tanks, dip tanks for lacquer coatings, electrical testing equipment, and other specialized equipment (NSRP, 1993).

Foundry/Blacksmith Shop

The blacksmith shop is an older term used for the shipyard shop that performs forging or castings. Forging and casting at shipyards are somewhat rare. Over the years, forging and casting functions have been shifted to subcontractors off-site. The subcontractors are usually foundries whose primary function is forging and casting. Shipyards that have blacksmith shops maintain large furnaces and other foundry equipment (NSRP, 1993).

Plate Shop

The plate shop is a generic term used for the area and process in the shipyard that provides steel parts cutting, bending, and sub-assembly. The plate shop uses information from engineering drawings to produce plate shapes. The shapes are cut and formed as needed. Most plate shops have manual and computer controlled machinery. The types of machinery commonly found in the plate shop are cutting machines, steel bending machines and plate bending rolls, shearing machines, presses, hole punching equipment, and furnaces for heat treatment. The plate shop sends the parts and sub-assemblies that they manufacture to the stages of construction, or the platen area for installation (NSRP, 1993).

Production Services

Services provided by this department include: carpentry, scaffolding erection, crane operations, rigging, facility and equipment maintenance, and other production support activities. The production services may be grouped into one department or divided into unique shops for each service provided (NSRP, 1993).

III.A.8. Solvent Cleaning and Degreasing

Solvent cleaning and degreasing are common in the shipbuilding and repair industry (although many facilities are replacing solvent cleaning and degreasing with aqueous and alkaline cleaning and degreasing). Solvent cleaning and degreasing are typically accomplished by either cold cleaning or vapor degreasing. Cold cleaning refers to operations in which the solvent is used at room temperature. The surfaces or parts are soaked in a tank of solvent, or sprayed, brushed, wiped, or flushed with solvent. Diphase cleaning is sometimes used to combine a water rinse before and after the solvent cleaning into a single step. In diphase cleaning, water insoluble halogenated solvents and water are placed in a single tank where they separate with the solvent on the bottom. Parts are lowered through the water bath before reaching the solvent and then are rinsed through the water level as they are removed from the tank.

In vapor degreasing, parts and surfaces are cleaned with a hot solvent vapor. Solvent in a specially designed tank is boiled creating a solvent vapor in the upper portion of the tank. The parts are held in the vapor zone where solvent vapor condenses on the surface removing dirt and oil as it drips back into the liquid solvent. In this way, only clean solvent vapors come in contact with the part. A condensing coils at the top of the tank reduces the amounts of solvents escaping to the atmosphere (NSRP, 1993).

III.A.9. Surface Preparation

To a large extent, the effectiveness of the surface coating relies on the quality of surface preparation. All paints will fail eventually, but the majority of premature failures are due to loss of adhesion caused by improper surface preparation. Surface preparation is also typically one of the most significant sources of shipyard wastes and pollutant outputs. Section III.B.1 discusses waste generation and pollution outputs from these operations.

Surface preparation techniques are used to remove surface contaminants such as mill scale, rust, dirt, dust, salts, old paint, grease, and flux. Contaminants that remain on the surface are the primary causes of premature failure of coating systems. Depending on the surface location, contaminants, and materials, a number of different surface preparation techniques are used in the shipbuilding and repair industry:

- Solvent, Detergent, and Steam Cleaning
- Blasting
- Hand Tool Preparation
- Wet Abrasive Blasting and Hydroblasting
- Chemical Preparation

Solvent, Detergent, and Steam Cleaning

The process of removing grease, oil and other contaminants with the aid of solvents, emulsions, detergents, and other cleaning compounds is frequently used for surface preparation in the shipbuilding industry. Solvent cleaning involves wiping, scrubbing, immersion in solvent, spraying, vapor degreasing, and emulsion cleaning the surface with rags or brushes until the surface is cleaned. The final wipe down must be performed with a clean rag or brush, and solvent. Inorganic compounds such as chlorides, sulfates, weld flux, rust and mill scale cannot be removed with organic solvents.

In many cases steam cleaning is a better alternative to solvent wipe down. Steam cleaning or high pressure washing is used to remove dirt and grime that is present on top of existing paint and bare steel. Many hot steam cleaners with detergents will remove most petroleum products and sometimes, old chipping paint. After steam cleaning the part should be rinsed with fresh water and allowed to dry. Often the surface is ready to prime, although many surfaces will require further preparation before painting.

Blasting

Abrasive blasting is the most common method for paint removal and surface preparation. Copper slag, coal slag, steel grit, and steel shot are common blasting abrasives. Copper and steel grit consist of small angular particles, while steel shot is made up of small round balls. Copper slag can generally be used only once or twice before it becomes too small to be effective. Steel grit and shot can typically be used between 50 and 5,000 times before becoming ineffective. Metallic grit and shot are available in varying ranges of hardness and size.

Centrifugal blasting machines, also called roto-blasting or automatic blasting, are one of the more popular methods of blasting steel surfaces. In centrifugal blasting, metallic shot or grit is propelled to the surface to be prepared by a spinning wheel. Centrifugal blasting machines tend to be large and not easily mobilized. Therefore, they are not applicable to all shipyard blasting needs. Parts to be prepared must be brought to the machine and passed through on a conveyor or rotary table. On flat surfaces, centrifugal blasting machines can produce uniform blasting results at high production rates. More time is required to prepare surfaces that are hard to reach. The process allows easy recovery of abrasive materials for reuse and recycling which can result in significant savings in materials and disposal costs. Large centrifugal blasting machines are often found in the prime line for preparing raw steel sheets before priming. Other centrifugal blasting machines are smaller and can be used to prepare small parts, pipe spools, and steel subassemblies prior to painting.

Air nozzle blasting (or dry abrasive blasting) is one of the most common types of blasting in the shipbuilding and repair industry. In air nozzle blasting, abrasive is conveyed to the surface to be prepared in a medium of high pressure air (approximately 100 pounds per square inch) through a nozzle at velocities approaching 450 feet per second. Abrasives are copper slag, coal slag and other metallic grit. Typically copper slag is used on the west coast and coal slag is used on the east coast. Traditionally sand was used, but metallic grit has replaced it due to the adverse health and environmental effects of silica dust associated with sand. Air nozzle blasting is generally carried out manually by shipyard workers either within a building or in the open air, depending on the application. If the application allows, blast booths can be used for containing abrasives.

Hand Tool Preparation

Hand tools such as grinders, wire brushes, sanders, chipping hammers, needle guns, rotary peening tools, and other impact tools are commonly used in the shipyard for surface preparation. The hand tools are ideal for small jobs, hard to reach areas, and areas where blasting grit would be too difficult to contain. Cleaning surfaces with hand tools seems comparatively slow although, when removing heavy paint formulations and heavy rust, they are effective and economical. Impact tools like chipping and needle guns are best for removing heavy deposits of brittle substances (e.g., rust and old paint). Hand tools are generally less effective when removing tight surface mill scale or surface rusting, because they can damage the metal surface. Surface preparation hand tools are generally pneumatic instead of electric because they are lighter, easy to handle, do not overheat, and there is no risk of electric shock.

Wet Abrasive Blasting and Hydroblasting

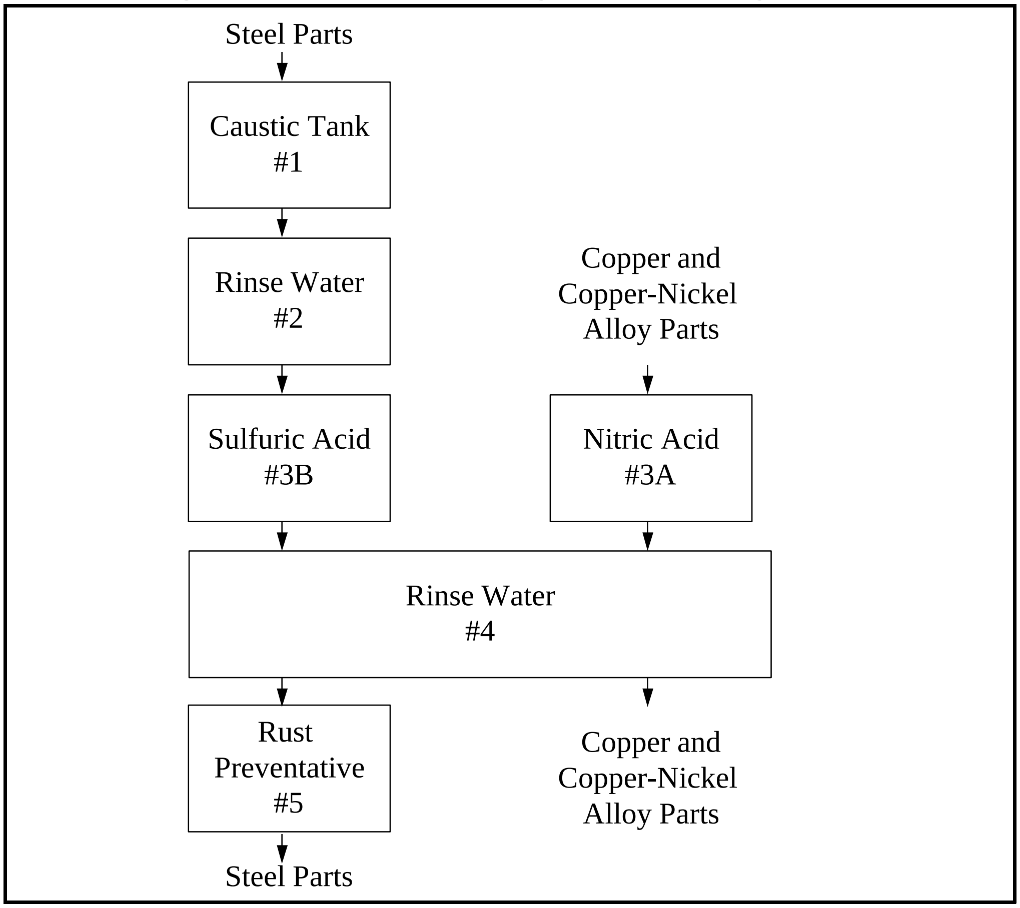
Wet abrasive blasting and hydroblasting are generally performed on ships being repaired in a floating drydock, graving dock, or other building or repair position. Wet abrasive blasting involves blasting with a mixture of water, air and solid abrasives. Wet abrasive blasting does not occur throughout the shipyard like dry abrasive blasting because of the problem of water blast containment. In part due to lack of customer acceptance, wet abrasive blasting is not common in the shipbuilding and repair industry at this time. Instead, hydroblasting is a widely used wet blasting technique which uses only high pressure water to remove chipping paint, marine growth, mud, and salt water from the ship's hull. A small amount of rust inhibitor may be used in the water to prevent flash rusting. Hydro basting is often followed by air nozzle blasting for final surface preparation.

Chemical Preparation

Chemical surface preparations consist of paint removers, alkaline cleaning solutions, chlorinated solvents, and pickling. Alkaline cleaning solutions come in a variety of forms and are used in a variety of manners. Alkaline cleaners can be brushed on, sprayed on, and applied in a dip tank. Alkaline dip tanks of caustic soda solution are frequently used for cleaning parts and preparing them for painting. After the surface is cleaned, it is thoroughly rinsed before a coating system is applied. Many solvents and alkaline cleaners cannot be used for nonferrous materials, such as bronze, aluminum, and galvanized steel which are frequently found on ships.

Pickling is a process of chemical abrasion/etching which prepares surfaces for good paint adhesion. The pickling process is used in shipyards mainly for preparing pipe systems and small parts for paint. However, the process and qualities will vary from shipyard to shipyard. The process involves a system of dip tanks. Figure 5 displays how the tanks can be arranged. In pickling steel parts and piping systems, Tank #1 is used to remove any oil, grease, flux, and other contaminants on the surface being pickled. The content in tank #1 are generally a 5-8% caustic soda and water mixture maintained at temperatures of between 180°-200°F. The part is then immersed into tank #2, which is the caustic soda rinse tank (pH 8-13). Next, the steel is dipped into tank #3B, which is a 6-10% sulfuric acid/water mixture maintained between 140°-160°F. Tank #4 is the acid rinse tank that is maintained at a pH of 5-7. Finally the steel pipe or part is immersed in a rust preventative 5% phosphoric mixture in tank #5. The part is allowed to fully dry prior to paint application.

Figure 5: Typical Pickling Tank Arrangement



Some ships have large piping systems that are predominantly copper-nickel alloy or copper. Pickling of copper is generally only a two-step process. The first step is to dip the pipe into tank #3A, a 3-6% nitric acid solution maintained at 140°-160°F. The nitric acid removes any flux and greases that are present on the surface and prepares the surface for paint. Next, the pipe is dipped into the acid rinse tank (#4), after which it is considered to be treated. Once the part is dry, the final coating can be applied.

Metal Plating and Surface Treatment

Metal plating and surface treatment are used in shipyards to alter the surface properties of the metal in order to increase corrosion or abrasion resistance, and to improve electrical conductivity (Kura, 1996). Metal plating and surface treatment includes chemical and electrochemical conversion, case hardening, metallic coating, and electroplating. Thorough descriptions of these processes and their associated wastes are contained in the *Fabricated Metal Products Industry Sector Notebook*.

III.A.10. Painting Processes

Proper surface coating system application is essential in the shipbuilding and repair industry. The corrosion and deterioration associated with the marine environment has detrimental effects on ships and shipboard components. Maintaining ships' structural integrity and the proper functioning of their components are the main purposes of shipboard coating systems.

Painting is performed at almost every location within shipyards. This is due to the wide variety of work performed throughout shipyards. The nature of shipbuilding and repair requires several types of paints to be used for a variety of applications. Paint types range from water-based coatings to high performance epoxy coatings. The type of paint needed for a certain application depends on the environment that the coating will be exposed. In general there are six areas where shipboard paint requirements exist:

- Underwater (Hull Bottom)
- Waterline
- Topside Superstructures
- Internal Spaces and Tanks
- Weather Decks
- Loose Equipment

Because paint systems are often specified by the customer or are supplied by the ship owner, shipyards often may not be able to choose or recommend a particular system. Navy ships may require a specific type of paint for every application through a military specification (Mil-spec). Many factors are considered when choosing a particular application. Among the factors are environmental conditions, severity of environmental exposure, drying and curing times, application equipment and procedures, etc.

Paint Coating Systems

Paints are made up of three main ingredients: pigment, binder, and a solvent vehicle. Pigments are small particles that generally determine the color as well as many other properties associated with the coating. Examples of pigments include: zinc oxide, talc, carbon, coal tar, lead, mica, aluminum, and zinc dust. The binder can be thought of as the glue that holds the paint pigments together. Many paints are referred to by their binder type (e.g., epoxy, alkyd, urethane, vinyl, phenolic, etc.). The binder is also very important for determining a coating's performance characteristics (e.g., flexibility, chemical resistance, durability, finish, etc.). The solvent is added to thin the paints so that it will flow to the surface and then dry. The solvent portion of the paint evaporates when the paint dries. Some typical solvents include acetone, mineral spirits, xylene, methyl ethyl ketone, and water.

Anticorrosive and antifouling paints are typically used on ship's hulls and are the main two types of paint used in the shipbuilding industry. Antifouling paints are used to prevent the growth of marine organisms on the hull of vessels. Copper-based and tributyl-tin-based paints are widely used as antifouling paints. These paints release small quantities of toxics which discourage marine life from growing on the hull. Anticorrosive paints are either vinyl, lacquer, urethane, or newer epoxy-based coating systems (ILO, 1996).

The first coating system applied to raw steel sheets and parts is generally pre-construction primer. This pre-construction primer is sometimes referred to as shop primer. This coat of primer is important for maintaining the condition of the part throughout the construction process. Pre-construction priming is performed on steel plates, shapes, sections of piping, and ventilation ducting. Most pre-construction primers are zinc-rich with organic or inorganic binders. Zinc silicates are predominant among the inorganic zinc primers. Zinc coating systems protect coatings in much the same manner as galvanizing. If zinc is coated on steel, oxygen will react with the zinc to form zinc oxide, which forms a tight layer that does not allow water or air to come into contact with the steel (ILO, 1996).

Paint Application Equipment

There are many types of paint application equipment used in the shipbuilding industry. Two main methods used are compressed air and airless sprayers. Compressed air sprayers are being phased out in the industry because of the low transfer ability of the system. Air assisted paint systems spray both air and paint, which causes some paint to atomize and dry quickly prior to reaching the intended surface. The transfer efficiency of air assisted spray systems can vary from 65% to 80%. This low transfer efficiency is due mainly to overspray, drift, and the air sprayer's inefficiencies (ILO, 1996).

The most widely used form of paint application in the shipbuilding industry is the airless sprayer. The airless sprayer is a system that simply compresses paint in a hydraulic line and has a spray nozzle at the end. Airless sprayers use hydrostatic pressure instead of air to convey the paint. They are much cleaner to operate and have fewer leaking problems because the system requires less pressure. Airless sprayers can have up to 90% transfer efficiency. A new technology that can be added to the airless sprayer is called High Volume Low Pressure (HVLP). HVLP offers an even higher transfer efficiency, in certain conditions (ILO, 1996).

Thermal spray is the application of aluminum or zinc coatings to steel for long term corrosion protection. Thermal spray can also be referred to as metal spray or flame spray. Thermal spray is significantly different than conventional coating practices due to its specialized equipment and relatively slow production rates. The initial cost of thermal spray is usually high compared to painting, although when the life-cycle is taken into account, thermal spray becomes more economically attractive. Many shipyards have their own thermal spray machines and other shipyards will subcontract their thermal coating work. Thermal spray can occur in a shop or onboard the ship. There are two basic types of thermal coating machines: combustion wire and arc spray. The combustion wire type consists of combustible gasses and flame system with a wire feed controller. The combustible gasses melt the material to be sprayed onto the parts. The electric arc spray machine instead uses a power supply arc to melt the flame sprayed material (ILO, 1996).

Painting Practices and Methods

Painting is performed in nearly every area in the shipyard from the initial priming of the steel to the final paint detailing of the ship. Methods for painting vary greatly from process to process. Mixing of paint is performed both manually and mechanically and should be done in an area contained by berms, tarps, secondary containment pallets. Outdoor as well as indoor painting occurs in the shipyard. Shrouding fences, made of steel, plastic, or fabric, are frequently used to help contain paint overspray by blocking the wind and catching paint particles (NSRP, 1996).

Hull painting occurs on both repair ships and new construction ships. Hull surface preparation and painting on repair ships is normally performed when the ship is fully drydocked (i.e., graving-dock or floating drydock). For new construction, the hull is prepared and painted at a building position using one of the techniques discussed in the previous sections. Paint systems are sprayed onto the hull using airless sprayers and high reach equipment such as man-lifts, scissor lifts, or portable scaffolding (ILO, 1996).

The superstructure of the ship consists of the exposed decks, deck houses, and structures above the main deck. In many cases, scaffolding is used onboard the ship to reach antennas, houses, and other superstructures. Shrouding is usually put into place if it is likely that paint or blast material will fall into adjacent waters. On repair ships, the ship's superstructure is painted mostly while berthed. The painters access the superstructures with existing scaffolding, ladders, and various lifting equipment that was used during surface preparation. The shrouding system (if applicable) that was used for blast containment will stay in place to help contain any paint overspray (ILO, 1996).

Tanks and compartments onboard ships must be coated and re-coated to maintain the longevity of the ship. Re-coating of repair ship tanks requires a large amount of surface preparation prior to painting. The majority of the tanks are at the bottom of the ship (e.g., ballast tanks, bilges, fuel, etc.). The tanks are prepared for paint by using solvents and detergents to remove grease and oil build-up. The associated waste-water developed during tank cleaning must be properly treated and disposed of. After the tanks are dried, they are blasted with a mineral slag. Once the surface is blasted and the grit is removed, painting can begin. Adequate ventilation and respirators are a strict requirement for all tank and compartment surface preparation and painting (ILO, 1996).

Painting is also carried out after the assembly of hull blocks. Once the blocks leave the assembly area, they are frequently transported to a blast area where the entire block is prepared for paint. At this point, the block is usually blasted back down to bare metal (i.e., the construction primer is removed). However, many shipyards are now moving towards implementing a preconstruction primer that does not need to be removed. The most frequent method for block surface preparation is air nozzle blasting. The paint system is applied by painters generally using airless spray equipment on access platforms. Once the block's coating system has been applied, the block is transported to the on-block stage where outfitting materials are installed (ILO, 1996).

Many parts need to have a coating system applied prior to installation. For example, piping spools, vent ducting, foundations, and doors are painted before they are installed on-block. Some small parts painting occurs in the various shops while others are painted in a standard location operated by the paint department (ILO, 1996). Indoor painting of this type usually occurs in a spray booth. Spray booths capture overspray, control the introduction of contaminants to the workplace environment, and reduce the likelihood of explosions and fires. Paint booths are categorized by the method used for collecting the overspray (EPA, 1995).

The two primary types of paint booths are dry filter and water wash booths. Dry filter booths use filter media (usually paper or cloth filters) to screen out the paint solids by pulling prefiltered air through the booth, past the spraying operation, and through the filter media. Water wash booths use a "water curtain" to capture paint overspray by pulling air containing entrained paint overspray through a circulated water stream which "scrubs" the overspray from the air. Water is periodically added to the paint booth reservoir to compensate for evaporative losses, and chemicals are periodically added to improve paint sludge formation. The sump is periodically discharged, usually during general system cleaning or maintenance (EPA, 1995).

III.A.11. Fiberglass Reinforced Construction Operations

Many of the medium and small shipyards manufacture and repair fiberglass ships and boats or construct fiberglass parts for steel ships. The process involves combining polymerizing resin with fiberglass reinforcing material. The resin is polymerized with a catalyst or curing agent. Once cured, the hard resin cannot be softened or reshaped and is stronger than composite plastics without the reinforcing. Fiberglass material consists of a woven mat of glass-like fibers. The fiberglass content of the reinforced product ranges from 25 to 60 percent.

A number of different processes are used, but the mold-based process is the most common for this industry. Mold-based fiberglass reinforced construction typically involves either the hand application or spray application of fiberglass reinforcing. In the hand application method, the reinforcing material is manually applied to a mold wetted with catalyzed resin mix or gelcoat and then sprayed or brushed with more resin or gelcoat. In the sprayup method, catalyzed resin and fiberglass reinforcement are mechanically sprayed onto the mold surface.

Molds are used to give structure and support to the shape of the structure being built. Most molds are made of wood with a plastic finish. Typical resins used include: polyesters, epoxies, polyamides, and phenolics. The type of resin to be used in a particular process depends on the specific properties required for the end product. The resin is supplied in liquid form and may contain a solvent. Resin preparation involves mixing with solvents, catalysts, pigments, and other additives. Solvents are typically acetone, methanol, methyl ethyl ketone, and styrene. Catalysts are typically amines, anydrides, aldehyde condensation products, and Lewis acid products. Gelcoat is a pigmented polyester resin or a polyester resin-based paint containing approximately 35 percent styrene that is applied to the mold or surface with an air atomizer or airless spray gun. A catalyst is injected into the resin in a separate line or by hand mixing in order to thermoset the polyester resin.

III.B. Raw Material Inputs and Pollutant Outputs

Raw material inputs to the shipbuilding and repair industry are primarily steel and other metals, paints and solvents, blasting abrasives, and machine and cutting oils. In addition, a wide variety of chemicals are used for surface preparation and finishing such as solvent degreasers, acid and alkaline cleaners, and cyanide and metal bearing plating solutions. Pollutants and wastes generated typically include VOCs, particulates, waste solvents, oils and resins, metal bearing sludges and wastewater, waste paint, waste paint chips, and spent abrasives. The major shipyard activities that generate wastes and pollutant outputs are discussed below and are summarized in Table 3.

III.B.1. Surface Preparation

The materials used and wastes generated during surface preparation depend on the specific methods used. The surface preparation method is chosen based on the condition of the metal surface (e.g., coated with paint, rust, scale, dirt, grease, etc.), the type of coating to be applied, the size, shape, and location of the surface, and the type of metal. Material inputs used for preparing surfaces include: abrasive materials such as steel shot or grit, garnet, and copper or coal slag; and cleaning water, detergents, and chemical paint strippers (e.g., methylene chloride-based solutions, caustic solutions, and solvents). In the case of hydroblasting, only water and occasionally rust inhibitor are required (NSRP, 1996).

Air Emissions

Air emissions from surface preparation operations include particulate emissions of blasting abrasives, and paint chips. Particulates emissions can also contain toxic metals which are a concern both in the immediate area surrounding the work and if they are blown off-site or into surrounding surface waters. Particulate emissions are typically controlled by preparing surfaces indoors when possible or by surrounding the work area with shrouding fences made of steel, plastic, or fabric. Other air emissions that could potentially arise during surface preparation operations are VOCs and hazardous air pollutants (HAPs) arising from the use of solvent cleaners, paint strippers, and degreasers.

Residual Wastes

The primary residual waste generated is a mixture of paint chips and used abrasives. Paint chips containing lead or antifouling agents may be hazardous, but often in practice the concentration of toxic compounds is reduced due to the presence of considerable amounts of spent blasting medium. The resulting mixed waste may be nonhazardous (Kura, 1996). Waste sludge containing paint chips and surface contaminants may also be generated in the case of hydroblasting or wet abrasive blasting. Blasting abrasives and paint chips that collect in tank vessels, ship decks, or drydocks should be thoroughly cleaned up and collected after work is completed or before the drydock is flooded or submerged. Particular attention should be paid to the cleanup of paint chips containing the antifouling tributyl-tin (TBT) compounds which have been shown to be highly toxic to oysters and other marine life (Levy, 1996).

Wastewater

Significant quantities of wastewater can be generated when cleaning ship cargo tanks, ballast tanks, and bilges prior to surface preparation and painting. Such wastewater is often contaminated with cleaning solvents, and oil and fuel from bilges and cargo tanks. Wastewater contaminated with paint chips and surface contaminants is generated when hydroblasting and wet abrasive blasting methods are used (EPA, 1991).

III.B.2. Painting

Material inputs for painting are primarily paints and solvents. Solvents are used in the paints to carry the pigment and binder to the surface, and for cleaning the painting equipment. VOCs and HAPs from painting solvents are one of the most important sources of pollutant outputs for the industry. Paints also may contain toxic pigments such as chromium, titanium dioxide, lead, copper, and tributyl-tin compounds. Water is also used for equipment cleaning when water-based paints are used.

Air Emissions

Painting can produce significant emissions of VOCs and HAPs when the solvents in the paint volatilize as the paint dries. Other sources of VOCs and HAPs may arise when solvents are used to clean painting equipment such as spray guns, brushes, containers, and rags. Sprayed paint that does not reach the surface being coated, or overspray, is another source of painting air emissions. The solvents in the overspray rapidly volatilize and the remaining dry paint particles can drift off-site or into nearby surface waters.

Residual Wastes

Solid wastes associated with painting are believed to be the largest category of hazardous waste produced in shipyards (Kura, 1996). Typical wastes associated with painting include leftover paint, waste paint containers, spent equipment, rags and other materials contaminated with paint, spent solvents, still bottoms from recycled cleaning solvents, and sludges from the sumps of water wash paint spray booths. Wastes associated with antifouling bottom paints are sometimes collected separately from the typically less toxic topside and interior paints. Antifouling paints contain toxic metal or organometallic biocides such as cuprous oxide, lead oxide, and tributyl-tin compounds. (Kura, 1996)

Wastewater

Wastewater contaminated with paints and solvents may be generated during equipment cleaning operations; however, water is typically only used in cleaning water-based paints. Wastewater is also generated when water curtains (water wash spray booths) are used during painting. Wastewater from painting water curtains commonly contains organic pollutants as well as certain metals. The wastewater can be treated at the source using filtration, activated carbon adsorption, or centrifugation and then reused instead of being discharged (EPA, 1995).

III.B.3. Metal Plating and Surface Finishing

Material inputs for metal plating and finishing include the solutions of plating metals such as chromium, aluminum, brass, bronze, cadmium, copper, iron, lead, nickel, zinc, gold, platinum, and silver. In addition, cyanide solutions, solvents, rinse water, and rust inhibitors are used. Many of the wastes generated from metal plating and surface finishing operations are considered hazardous resulting from their toxicity. Thorough descriptions of these processes and their associated wastes are contained in the *Fabricated Metal Products Industry Sector Notebook*.

Air Emissions

Air emissions arise from metal mists, fumes, and gas bubbles from the surface of the liquid baths and the volatilization of solvents used to clean surfaces prior to plating or surface finishing.

Residual Wastes

Solid wastes include wastewater treatment sludges, still bottoms, spent metal plating solutions, spent cyanide solutions, and residues from tank cleaning. Often, the solid waste generated contains significant concentrations of toxic metals, cyanides, acids, and alkalies.

Wastewater

Wastewaters are primarily rinse waters, quench water, and waste tank cleaning water contaminated with metals, cyanides, acids, alkalies, organics, and solvents. Wastewaters are typically either sent off-site for treatment or disposal or are treated onsite by neutralization and conventional hydroxide precipitation prior to discharging either to a POTW or surface waters under an NPDES permit.

III.B.4. Fiberglass Reinforced Construction

Material inputs for fiberglassing operations include fiberglass, mold or reinforcing materials (wood and plastic), resins, solvents, and curing catalysts. Unsaturated polyester resins, such as orthophthalic polyester, isophthalic polyester, and bisphenol polyester are the most commonly used resins. Other resins include epoxies, polyamides and phenolic compounds. Resins typically are not hazardous; however, the solvent in which the resin is dissolved may be hazardous. In addition, some catalysts may be hazardous. Catalysts include amines (e.g., diethylenetriamine and triethylenetetramone), anhydrides, aldehyde condensation products, and Lewis acid catalysts.

Typical hazardous wastes include containers contaminated with residual chemicals, wash-down wastewater, spent cleaning solvents from equipment cleanup, scrap solvated resin left over in mix tanks, diluted resin and partially cured resin. For a detailed description of fiberglassing operations and associated wastes, refer to EPA's *Pollution Prevention Guide for the Fiberglass-Reinforced and Composite Plastics Industry, October 1991*.

Air Emissions

Organic vapors consisting of VOCs are emitted from fresh resin surfaces during the fabrication process and from the use of solvents for cleanup. The polyester resins used in gelcoating operations have a styrene content of approximately 35 percent. Emissions of styrene and other solvent VOCs during spraying, mixing, brushing, and curing can be significant. In addition, emissions of solvent vapors arise when acetone and methylene chloride are used to clean fiber glassing equipment (Kura, 1996).

Residual Wastes

Residual wastes generated from fiberglass operations include, gelcoat and resin overspray, unused resins that have exceeded their shelf life, fiberglass boxes, gelcoat drums, waste solvents, and cleanup rags (Kura, 1996).

III.B.5. Machining and Metalworking

Machining and metal working operations such as cutting, pressing, boring, milling, and grinding, typically involve the use of a high speed cutting tool. Friction at the cutting edge of the blade creates heat that could permanently deform the metal being machined or the cutting tool. Coolants, such as cutting oils and lube oils are, therefore, supplied to the leading edge of the tool to remove excessive heat (Kura, 1996). Solvents are frequently used to clean parts and tools prior to and after machining.

Air Emissions

Fugitive air emissions arise from the use of solvents for cleaning and degreasing.

Residual Wastes

Waste cutting oils, lube oils, and degreasing solvents are the major residual wastes generated. Metal shavings and chips are also generated. Typically these are separated from coolants, if necessary, and recycled along with scrap metal (Kura, 1996).

Wastewater

Wastewaters containing cleaning solvents and emulsified lubricants, coolants, and cutting oils may produced if parts are cleaned or rinsed with water. In addition, some modern lubricating oils and grease are being formulated with limited or no mineral oil content. These lubricants are known as high water content fluids. When spent they can result in wastewater comprised of a maximum of 15 percent mineral oil emulsified in water (Water Environment Federation, 1994).

III.B.6. Solvent Cleaning and Degreasing

The type of solvent used in parts and surface cleaning and degreasing depends on the type of contaminants to be removed, degree of cleaning needed, properties of the surfaces to be cleaned, and properties of the various solvents (stability, toxicity, flammability, and cost). Both halogenated and nonhalogenated solvents are used and mixtures of different solvents are common. Typical cleaning and degreasing solvents include mineral spirits, aromatic hydrocarbons (e.g., xylenes, toluene, etc.), aliphatic hydrocarbons, ketones, esters, alcohols, glycol ethers, phenols, turpentine, and various halogenated solvents (e.g., trichloroethylene, 1,1,1-trichloroethane, perchloroethylene, etc.).

Air Emissions

Solvent vapors comprised of VOCs and HAPs are a significant pollutant output of cleaning and degreasing operations. Fugitive emissions arise from vapor degreasers, solvent tanks and containers, solvent stills, solvent soaked rags, and residual solvents on parts and surfaces.

Residual Wastes

Residual wastes may include contaminated or spent solvents, solvents that have become contaminated or deteriorated due to improper storage or handling, solvent residues and sludges from tank bottoms and still bottoms, solvent contaminated rags and filter cartridges, and solvent contaminated soil from solvent spills.

Wastewater

Wastewater containing solvents are generated when cleaning or rinsing parts or surfaces, and when cleaning equipment, tanks, and process lines with water. Wastewater contaminated with solvents is also generated when water from diphase parts cleaning operations is replaced.

Table 3: Material Inputs and Potential Pollutant Outputs for the Shipbuilding and Repair Industry

Industrial Process	Material Inputs	Air Emissions	Wastewater	Residual Wastes
Surface Preparation	Abrasives (steel shot, lead shot, steel grit, garnet, copper slag, and coal slag), detergents, solvent paint strippers and cleaners, and caustic solutions.	Particulates (metal, paint, and abrasives) and VOCs from solvent cleaners and paint strippers.	Wastewater contaminated with paint chips, cleaning and paint stripping solvents, surface contaminants, and oil residues from bilges and cargo tanks.	Paint chips (potentially containing metals, tributyl-tin), spent abrasives, surface contaminants, and cargo tank residues.
Metal Plating and Surface Finishing	Plating metals, cyanide solutions, cleaning solvents, rinse water, acid and caustic solutions and rust inhibitors.	Metal mists and fumes, and VOCs from solvents.	Rinse and quench water contaminated with metals, cyanides, acids, alkalies, organics, and solvents.	Sludge from wastewater treatment, spent plating solutions and cyanide solutions, bath cleaning residues.
Painting	Paints, solvents, and water.	VOCs from paint solvents and equipment cleaning solvents, and overspray.	Waste equipment cleaning water and water wash spray paint booth sump water contaminated with paints and solvents.	Leftover paint and solvents, waste paint and solvent containers, spent paint booth filters, and spent equipment.
Fiberglass Reinforced Construction	Fiberglass, resin, solvents, curing catalysts, and wood and plastic reinforcing materials.	VOC emissions released during construction operations and curing (e.g., styrene) and during cleaning with solvents (e.g., acetone and methylene chloride).	Little or no wastewater generated.	Waste fiberglass, gelcoat, resin, unused resin that has exceeded its shelf life, spent solvents, and used containers.
Machining and Metal Working	Cutting oils, lube oils, and solvents.	VOC emissions from the use of cleaning and degreasing solvents.	Wastewater containing solvents, emulsified lubricating and cutting oils and coolants.	Waste cutting oils, lube oils, and metal chips and shavings.

Sources: Kura, Bhaskar, *Typical Waste Streams in a Shipbuilding Facility*, and U.S. EPA, Office of Research and Development, *Guides to Pollution Prevention, The Marine Maintenance and Repair Industry.*

III.C. Management of Chemicals in Wastestream

The Pollution Prevention Act of 1990 (PPA) requires facilities to report information about the management of Toxics Release Inventory (TRI) chemicals in waste and efforts made to eliminate or reduce those quantities. These data have been collected annually in Section 8 of the TRI reporting Form R beginning with the 1991 reporting year. The data summarized below cover the years 1993-1996 and is meant to provide a basic understanding of the quantities of waste handled by the industry, the methods typically used to manage this waste, and recent trends in these methods. TRI waste management data can be used to assess trends in source reduction within individual industries and facilities, and for specific TRI chemicals. This information could then be used as a tool in identifying opportunities for pollution prevention compliance assistance activities.

While the quantities reported for 1994 and 1995 are estimates of quantities already managed, the quantities listed by facilities for 1996 and 1997 are projections only. The PPA requires these projections to encourage facilities to consider future waste generation and source reduction of those quantities as well as movement up the waste management hierarchy. Future-year estimates are not commitments that facilities reporting under TRI are required to meet.

Table 4 shows that the TRI reporting shipyards managed about six million pounds of production related wastes (total quantity of TRI chemicals in the waste from routine production operations in column B) in 1995. From the yearly data presented in column B, the total quantities of production related TRI wastes increased between 1994 and 1995. This is likely in part because the number of chemicals on the TRI list nearly doubled between those years. Production related wastes were projected to decrease between 1996 and 1997.

Values in column C are intended to reveal the percentage of production related wastes that are either transferred off-site or released to the environment. Column C is calculated by dividing the total TRI transfers and releases (reported in Sections 5 and 6 of the TRI Form R) by the total quantity of production-related waste (reported in Section 8). Since the TRI releases and transfers from Sections 5 and 6 of the TRI Form R should all be accounted for in Section 8 of Form R, the percentages shown in column C should always be less than 100 percent. For the shipbuilding and repair industry, the TRI data shows that erroneous reporting in Form R by a number of shipyards in both 1994 and 1995 has undermined the data resulting in unusually high values in Column C.

If it is assumed that the proportions of production related wastes managed onsite and off-site using the methods shown in columns D-I were reported correctly, the data would indicate that about 60 percent of the TRI wastes are managed off-site through recycling, energy recovery, or treatment (columns G, H, and I, respectively) in 1995. Only about one percent of the wastes were managed on-site. The remaining portion of TRI chemical wastes (about 44 percent), shown in column J, were released to the environment through direct discharges to air, land, water, and underground injection, or was disposed off-site.

Table 4: Source Reduction and Recycling Activity for Shipyards (SIC 3731) as Reported within TRI

A	B	C	On-Site			Off-Site			J
			D	E	F	G	H	I	
Year	Quantity of Production-Related Waste (10^6 lbs.)[a]	% Released and Transferred[b]	% Recycled	% Energy Recovery	% Treated	% Recycled	% Energy Recovery	% Treated	% Released and Disposed[c] Off-site
1994	5.32	113%	1.1%	0.0%	0.7%	36.1%	12.6%	3.6%	46%
1995	6.45	100%	0.5%	0.0%	0.7%	45.7%	11.2%	2.2%	44%
1996	5.62	---	0.7%	0.0%	0.7%	40.1%	11.3%	3.1%	44%
1997	5.59	---	0.8%	0.0%	0.7%	40.6%	11.1%	3.1%	44%

Source: *1995 Toxics Release Inventory Database.*

[a] Within this industry sector, non-production related waste < 1% of production related wastes for 1995.

[b] Total TRI transfers and releases as reported in Section 5 and 6 of Form R as a percentage of production related wastes.

[c] Percentage of production related waste released to the environment and transferred off-site for disposal.

Page 42 intentionally left blank.